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ABSTRACT

An evaluation of four seventeenth and eighteenth century essays on optics revealed early trends in the evolution of scientific articles. The later articles showed a growing tendency to (1) separate practice from pure knowledge, (2) organize information around problems of knowledge and theory rather than around chronological events, (3) emphasize the rhetorical focus of the experimental design and report, and (4) accept individual responsibility for research results. In addition, the later works differed from the earlier ones in their methods of persuasion. They no longer used ostentatious descriptions of single observations, but presented plain narratives of repeated observations; they emphasized the accuracy of their theories not by relying on self-evident truths but by devising experiments to prove their theoretical points; and they stressed the importance of their findings by showing how their research contributed to the advancement of knowledge rather than by suggesting its practical significance. This development of argumentative patterns continues, in a more advanced form, in contemporary research. (MM)

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Early Developments in Argumentation in Physics

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A physicist writing an experimental report needs to convince the readers of three things: the physicist has indeed found something in nature; the account given of the phenomenon is accurate; and the finding is of importance. If there is any moral, however, in the last twenty years' work in the philosophy, history, and sociology of science,[1] it is that the acts of finding, giving an account, and attributing importance embody complex epistemological and social components for both the individual investigator and the evaluating community of peers. The argument of the text necessarily operates within these complexities.

This essay will examine four moments in the early journal literature on optics to examine how epistemological and social considerations were worked out in texts during the period when the form of the scientific article was first being invented.[2] The evolving state of the scientific article itself becomes a social fact, defining what the scientist hopes and is expected to accomplish; that is, the scientist will write in a way resembling what is then thought to be an appropriate way to write about the subject. For such reasons an understanding of the evolution of the scientific article will help us understand why today scientists write as they do.

The scientific article began its evolution in 1665 with the appearance of the first two scientific journals: the Journal des Sçavans in Paris and the Philosophical Transactions of the Royal Society of London. The examples here are all experimental reports from the latter. The early issues of the Philosphical Transactions reported many items, from the birth of a monstrous calf to the latest navigational tools and medical nostrums. The physics was limited and more observational than experimental: even when an item was labelled an experiment it could just as well be a cookbook recipe for producing a woundrous effect as an inquiry-directed constructed set of events. However, the first article in volume I, number 1, immediately after the editorial explaining the founding and purposes of the journal, does report an advance in optics with a kind of experimental component. It begins

> There came lately from Paris a Relation, concerning the Improvement of Optick Glasses, not long since attempted at Rome by Signor Giuseppe Campani, and by him discoursed of, in a Book, Entituled, Ragguaglio di nuoue Osservationi, lately printed in the said City, but not yet transmitted into these parts; wherein these following particulars, according to the Intelligence,

which was sent hither, are contained.

> The first regardeth the excellency of the long Telescopes, made by the said Campani, who pretends to have found a way to work great Optick Glasses with a Turne-tool, without any Mould: And whereas hitherto it hath been found by Experience, that small Glasses are in proportion better, to see with, upon the Earth, then the great ones; that Author affirms, that his are equally good for the Earth, and for making Observations in the Heavens. Besides, he useth three Eye-Glasses for his great Telescopes, without finding any Iris, or such Rain-bow colors, as do usually appear in ordinary Glasses, and prove an impediment to Observations.[3]

This reports a claim only; some details, but no evidence, are given. There is no apparent argument, the moreso because the claim is presented through the third person voice of the editor Henry Oldenbourg, as were all reports in the early issues. An implicit argument, nonetheless, is made, based on the simplified Baconianism then popular: nature is open to the observant, and the scientific claim merely points. The proof is when others look where the finger is pointing and agree that they see the thing. Thus meetings of the Royal Society and the Royal Academy of Paris were often demonstrations

which the attendees would either confirm or deny. In such a situation the original claim-maker may have been most fortunate in having seen or done something first, but the claim immediately becomes communal; in fact, for the first few years the findings of the Parisian academy were published anonymously and corporately.[4] Thus the third person editor is in no less a position to report a claim than the original observer. Through his tone Oldenbourg presents some skepticism, but he mostly keeps his distance, waiting for the ocular proof.

Also worth noting is that the advance in optics is presented only as a practical matter. The practical problem is to make a more powerful but still accurate telescope; the solution requires two advances, one in grinding technique and the other in overcoming "the Iris," or prismatic splitting by the lenses. The latter clearly raises issues of optical theory, but it is here treated only concretely as a practical issue of telescope construction.

After a few issues of the journal, Oldenbourg began to quote directly from letters and other communications at increasing length; by the third volume articles stand independently as authored pieces so that investigators now presented their own claims in their own voices. The primary observer not only had more to say on the finding from closer experience but had more motive to present the findings persuasively. Thus the reports become more explicit, extended,

and advocatory. Yet the representative voice of communal judgment remained, moving from the editor to the reporting scientist, who could present his reactions to be those of any reasonable person forced by nature into startling realizations. Expressions of surprise and temporary disbelief at curious findings relieve the scientist of the taint of bias and suggest that the reader too would have been forced to the same conclusions..

Consider, for example, Isaac Newton's article "A New Theory of Light and Colors" from volume VI, February 1672,[5] presenting the finding that different colors were properties of different rays, with different degrees of refraction (refrangibility was another then current term.) The article begins with a first person narrative leading from amusement ("a very pleasing divertisement, to view the vivid and intense colours produced [by a triangular prism]") to surprise to concern for the problems raised by observations contrary "to the received laws of refraction." He makes further tests to eliminate potential variables. To this point the article is filled with the language of bemusement, then uncertainty; the early experiments are described only sketchily and qualitatively. He presents himself as orderly, knowledgeable, and observant as necessary to be perplexed by the observations, which in turn are presented clearly, but in no greater detail than that needed to warrant the perplexity. Newton presents

himself as acting as any of his peers would act, thereby enlisting their trust and assent even if they themselves have not observed the experiments.[6]

At this point, however, Newton resolves the perplexity with the "Experimentum Crucis," and the tone of the article changes immediately. The crucial experiment is described in detail, precisely, and somewhat quantitatively. As the experiment progresses, focus shifts from Newton's experimental doings to the phenomena of nature; the paragraph ends with an extended proposition in the third person concerning the nature of light. Newton no longer carries his peers along on a first person journey of discovery, but now speaks authoritatively. Having gone on the journey, he claims the right of the trusted representative to be believed.

Newton then further elucidates his theory of colors, but entirely through a series of numbered general propositions presented for the most part without further discovery process or proof. When he does mention his experiments briefly, as in the third proposition, it is to reassert his right to make general claims: "I have refracted it with prisms, and reflected it with bodies...;intercepted it with the coloured film of air; transmitted it through coloured mediums,.., and diversely terminated it; and yet could never produce any new colour out of it." In the eleventh and twelfth propositions

he mentions the observations of others to demonstrate the explanatory power of his new theory; this moves to a whole new level of proof. The ocular proof seems to have gone through a strange transformation. In the first part of the article, Newton attempts to persuade the readers to hand over their ocular judgment through vicarious observation; in the middle, Newton having obtained the ocular proxy leaves vicarious observation behind to present his conclusions; towards the end, Newton returns to the observations of others, but only to show the consequences of his theory are observationally accessible. These observations, further, are not transparently meaningful because they were puzzles until Newton's explanatory theory. Newton's discoveries may have been made through experiment, but the process remains within Newton's experience, which the readers are not entrusted with, but are asked to trust. Yet, even though Newton is entrusted with the ocular proxy, the underlying argument remains that observed nature is self-explanatory to those that do have access to the observations. Unfortunately, only a few can gain access.

Eighty-six years later in 1758, volume L, in "An Account of some Experiments concerning the different Refrangibility of Light" by John Dollond,[7] we see further evolution in voice and argument as another solution to the problem of limited accessibility to primary observations is developed. The communal voice remains, but separated from the main voice of the article, which is freed to develop a demonstrating argument.

The article is prefaced by a short letter from James Short, attesting that he has examined telescopes made according to Dollond's theory, which he has found are "intirely free from colours, and are as distinct as reflecting telescopes." Short's testimonial reasserts the community's interest in the ocular and practical proof, but recognizes that most of the community will not have observational access to make up their own minds.

Dollond is then freed from the responsibility of being the representative of all scientists. Dollond presents a narrative of discovery that the reader may judge for methodological and intellectual rigor, one that the reader may even reproduce if so motivated, but not one that carries the reader along a vicarious emotional path.[8] The account contains no affective responses to self-evidently meaningful and remarkable observations, but rather presents a sequence of logically conceived tests to answer specific questions leading to a solution of the basic problem. Dollond uses the experiments to make an argument, for which he is individually responsible. The finger pointing to nature, which for Newton became a pedagogue's pointer, here becomes the finger in the other guy's chest.

Further the source of the problem discussed starts to turn from the practical one of telescope construction or personal one of perplexity to the general one of the proper and full

account of nature. Although the article is prefaced by a testimonial on the practical problem, and the article ends with five pages applying the new theory to telescope construction as a kind of practical proof, the opening half, which comprises the main body of the argument is a generalized investigation of prismatic splitting during refraction, the only mention of the practical work of opticians being to uncover prevailing beliefs to be tested. The first three paragraphs present what is known about the phenomenon, and the fourth presents the opticians' beliefs to be questioned. The fifth paragraph raises the question, and the sixth begins description of a series of experiments and their discussion. Seeing nature is not enough; you must argue forcefully for the proper account.

The argument over the account to be given of nature requires a more extensive reliance on and discussion of previously gained knowledge. In the first report examined, prior knowedge was at most implicit in Oldenbourg's skeptical tone. In the Newton article, prior knowledge was touched on only lightly to identify an anomaly to the "received laws of refraction," and suggest puzzles solved by the new theory. But here Dollond begins by gathering together the extant account of the phenomenon and then discusses at some length the belief to be tested; the experiments and their discussion then become a critique of the prior belief as well as a proof of the new account.

In volume XC, William Herschel's article "Investigation of the Powers of the prismatic Colours to heat and illuminate Objects..." indicates that by 1800 the issue of the generalized account of phenomena becames even more prominent.[9] It begins

> It is sometimes of great use in natural philosophy, to doubt of things that are commonly taken for granted; especially as the means of resolving any doubt, when once it is entertained, are often within our reach. We may therefore say, that any experiment which leads us to investigate the truth of what was before admitted upon trust, may become of great utility to natural knowledge.

The basic problem is thus defined as proper understanding of a nature that is not always self-evidently revealing. The immediate task is to question received knowledge through available experimental techniques. The example of received knowledge then cited, that all colors are equally effective in heating and illuminating, is called into question on the basis of some astronomical experiments during which Herschel viewed the sun through colored glass filters on his telescope.

Once the immediate issue is identified through experimental experience, the main experimental narrative is not a process of discovery, but a sequence of proofs and refinements of

the hypothesis that different colors have different heating and illuminating powers. The [illegible] sequence of eight experiments on heating power and ten experiments on illuminating power, each experiment consisting of many trials for the different colors, serves as justification of his claims to the point of inductive tedium. The experiments are arranged around the principles to be expounded upon rather than around the psychological process of discovery. Herschel then discusses the relationship of the heat experiments and the illumination experiments, to postulate heat transmitted by invisible light (what we now call infra-red) and suggest further experiments.

Greater distance is created between writer and audience as Herschel presents himself in possession of a truth of which the audience must be persuaded through the narration of experiments. The ocular proof has been replaced by the written proof in which the narration and discussion stand in place of self-evident observed events. Herschel's readers need never witness his experiments to find the argument convincing. Ultimate acceptance will rely on either replication of the experiments or consistent results from related experiments, so some communal representatives will report ultimately some kind of ocular proof or absence of disconfirmation. But even though acceptance may be a long-term affair, involving post-argument experience, Herschel makes his argument complete in the moment

of presentation.

The attention we say turning to nature at the middle of Newton's essay and gaining prominence in Dollond's here takes center stage. Nonetheless, the narratives of discovery and application are not yet abandoned, but relegated to latter sections after the issues of natural knowledge have been resolved. Even though each section is chronologically arranged, this disruption of overall chronology in the service of an argumentative structure is a major rhetorical advance.

If we return to the three persuasive tasks of the physicist that I mentioned at the beginning of this essay, we can see the major changes occuring in argumentation. Persuasion of the observation moves from ostention to a narrative account that stands in place of the demonstration; a single personal observation is replaced by repeated reported events. Persuasion of the accuracy of the account moves from the self-evident truth of the observation to the selection and construction of experiments to prove specific theoretical points; theoretical coherence as well as experimental support of theory become important. Persuasion of importance changes from evidence of practical use to the advance of natural knowledge. Socially and epistemologically we move from an immanent world accessible to all observers, all of whom share similar powers to a puzzling world, to be plumbed by those of special situation and talent, who must then argue their ingenious inquiries and

conclusions before an audience who has neither seen the same sights nor finds the meaning of those sights self-evident.

The tendencies revealed in the changes in these four early journal articles are consistent with what I have found in more advanced form in more recent articles: divorce between practice and pure knowledge, decreasing chronology and increasing organization around problems of knowledge and theory, growing accumulation and integration of knowledge, increasing specialization and rhetorical focus of experimental design and report, and increasing individual responsibility for and ownership of the individual piece of research even as the focus of the presentation turns away from the investigation to general claims about nature.[10] Further, the tension between the argument by ostention, which always remains an undercurrent in both short and long-term acceptance of a claim, and the developing argument from theory and the written representation of experiment is linked to the issue of how the scientist as writer in the process of writing holds his linguistic construction accountable to nature.[11] Finally, all these trends are consistent with what I am currently finding about the reading processes of contemporary physicists, who, in understanding and evaluating the work of their peers, seem to invoke complex schema not only of current knowledge, but of the problems the field is

addressing and the most fruitful means of solving those problems. That is, persuading and being persuaded in physics are increasingly complex issues of the evolving social and intellectual structures of the discipline.

NOTES

[1]Frederick Suppe, The Structure of Scientific Theories, second edition (Urbana: University of Illinois Press, 1977) provides a comprehensive review of recent work in the philosophy of science; two reviews of the sociology of science from different perspectives are Steven Shapin, "History of Science and its Sociological Reconstruction," History of Science 20:3 (September 1982), pp. 157-211. and Charles Bazerman, "Scientific Writing as a Social Act" in New Essays in Technical and Scientific Communication, eds. Anderson, Brockmann, and Miller (Farmingdale, N.Y.: Baywood Publishing Co., 1983), pp. ; the work in history of science is too vast to be encompassed in a single review.

[2]I must emphasize that this study is only concerned with the argument made in the text, and not with the actual process of research through which the text is created. The experimental article will inevitably contain representations of the research process, and those representations are in the domain of this study. But the issue of how those representations relate to actual events is beyond the scope of both this study and available evidence.

[3]Philosophical Transactions 1:1 (March 1665), p. 2.

4 Roger Hahn, The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666-1803 (Berkeley: Univ. of California Press, 1971), pp. 26-28.

[5]Philosophical Transactions VI:80 (February 1672) reprinted in W. F. Magie, ed., A Source Book in Physics (Cambridge, Mass.: Harvard University Press, 1965), pp. 298-305.

[6]This example bears a limited similarity to David Dobrin's suggestion in "What Does Objectivity in Technical Language Do?" (delivered at MLA, New York, 1981) that objectivity consists of acting as any member of one's community would, which would then entail one to consider oneself as a kind of object. The case could certainly be made that Newton here is turning himself into a rhetorical object. But curiously, in the context of seventeenth century science, this process of objectifying oneself did not entail stripping oneself of affective elements, rather it was the wonder, surprise and puzzlement that made one similar to and representative of one's peers. What such objectivity, acting as anyone, would mean later when a more independent and adversary rhetorical relationship among scientific peers develops requires further elucidation.

[7]Philosophical Transactions L, part 2 (1758), pp. 733-743.

[8]This and the following example seem to support in textual strategy the suggestion of Bruno Latour and Steve Woolgar in Laboratory Life (Beverly Hills: Sage, 1979), pp. 81-86 that persuasion of scientific claims requires removing the claim from the local laboratory context in which the finding was made.

[9]Philosophical Transactions XC, part II (1800), pp. 255-284.

[10]Charles Bazerman, "The Emergence of the Modern Physics Article: A Stylistic History of Physical Review, 1893-1980 " unpublished manuscript, presented at the Society for the Social Studies of Science, Philadelphia, October 1982.

[11]Charles Bazerman, "The Writing of Non-Fiction: Contexts, Choices, and Constraints in a Scientific Paper," unpublished manuscript.

[12]Charles Bazerman, " The Reading Processes of Research Physicists," work in progress.